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Post-Shot Radiation Environment in the National Ignition Facility

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Post-Shot Radiation Environment in the National Ignition Facility

**Presentation to
12th International Conference on Radiation Shielding**

**Nara, Japan
September 5, 2012**



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Luisa Hansen, Soon Kim, Bert Pohl, Shiva Sitaraman, and Jerome Verbeke**

Lawrence Livermore National Laboratory • National Ignition Facility & Photon Science

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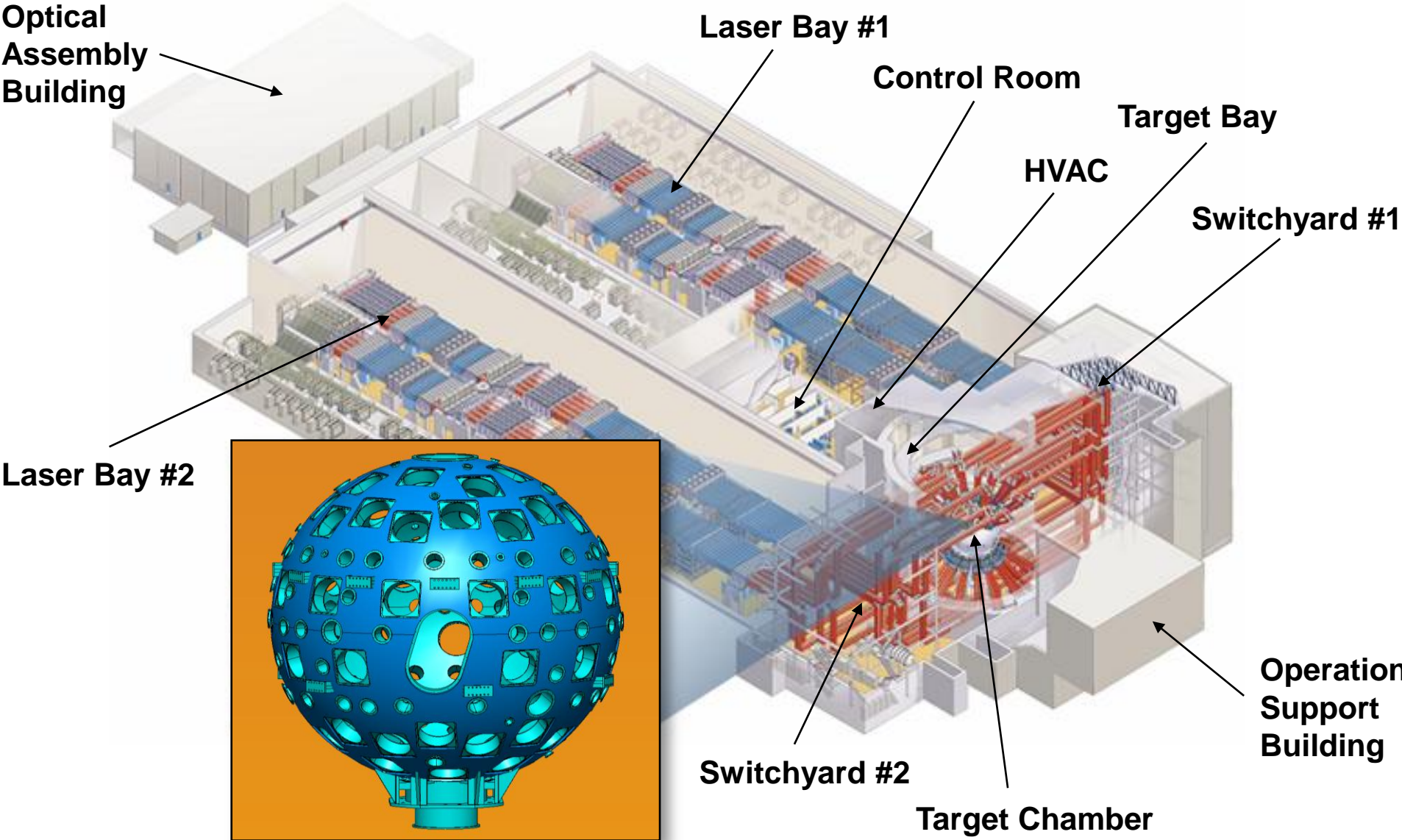
Outline

- I. The NIF facility modeling**
- II. Development of planning tools for estimating radiation exposure**
- III. Results of activation analysis**
- IV. Gamma spectrometry**
- V. Worker dose management**

Introduction

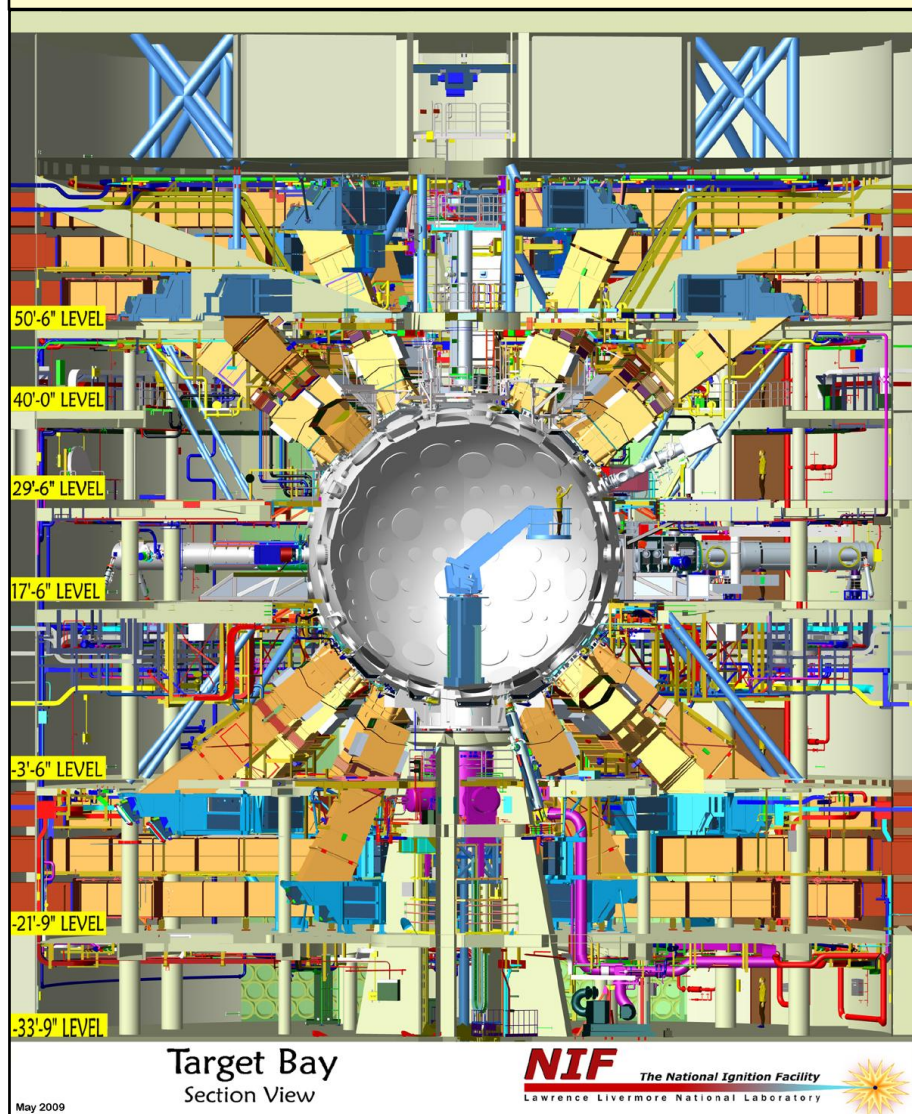
- A detailed 3-D model of NIF Target Bay (TB) has been developed
- An automated mechanism has been developed to allow for simultaneous analysis of contribution from all activated structures inside the TB
 - AAMI (*Automated ALARA-MCNP Interface*) is a coupling scheme between radiation transport and neutron activation codes
 - NEET (*NIF Exposure Estimation Tool*) is a web application that combines the information computed by AAMI with a given shot schedule to compute and display dose rate maps as a function of time
- Work planners can use NEET to estimate individual worker dose based on time required for a specific activity and for a specific location
- Estimated dose rate values are verified through the use of gamma spectrometry and passive dosimeters

NIF layout

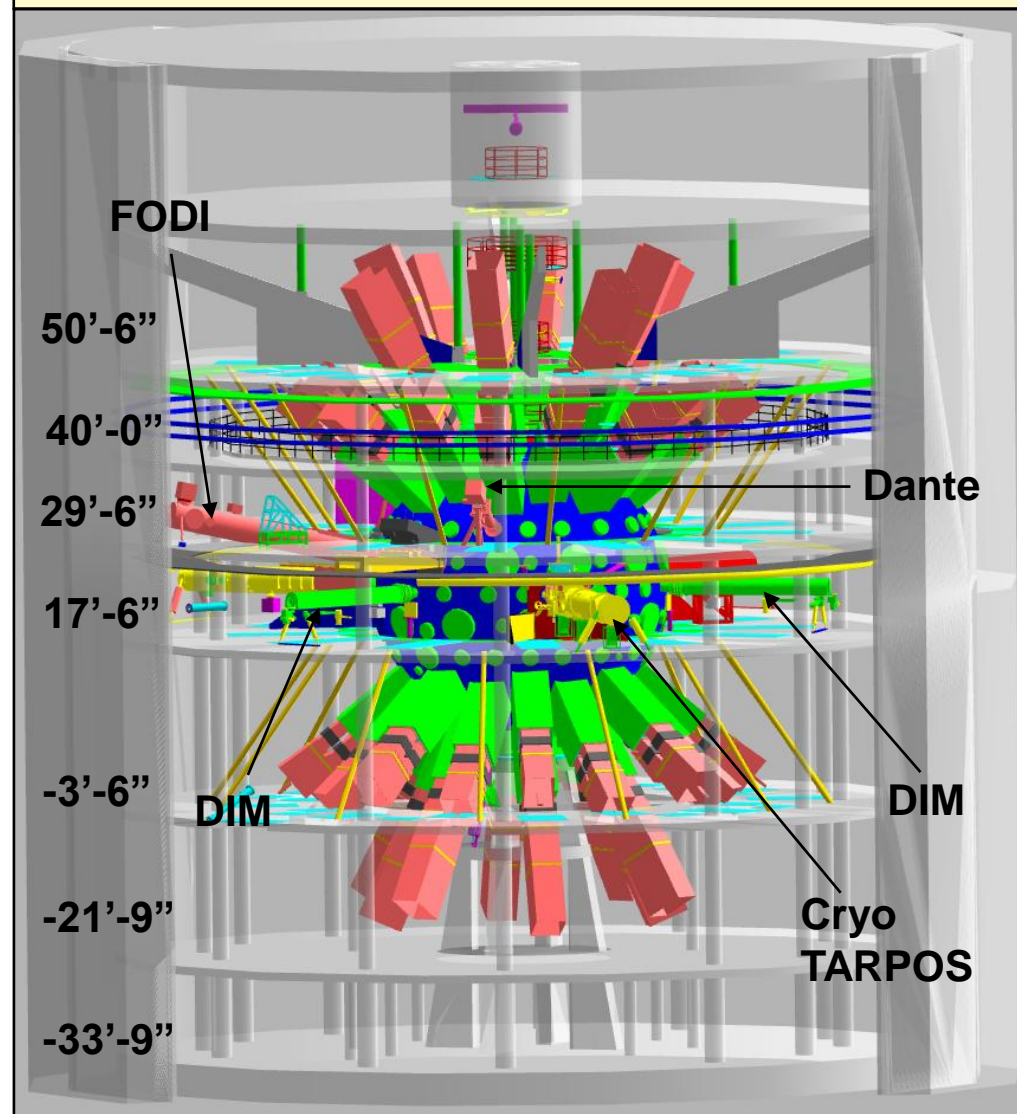


NIF Target Bay Model

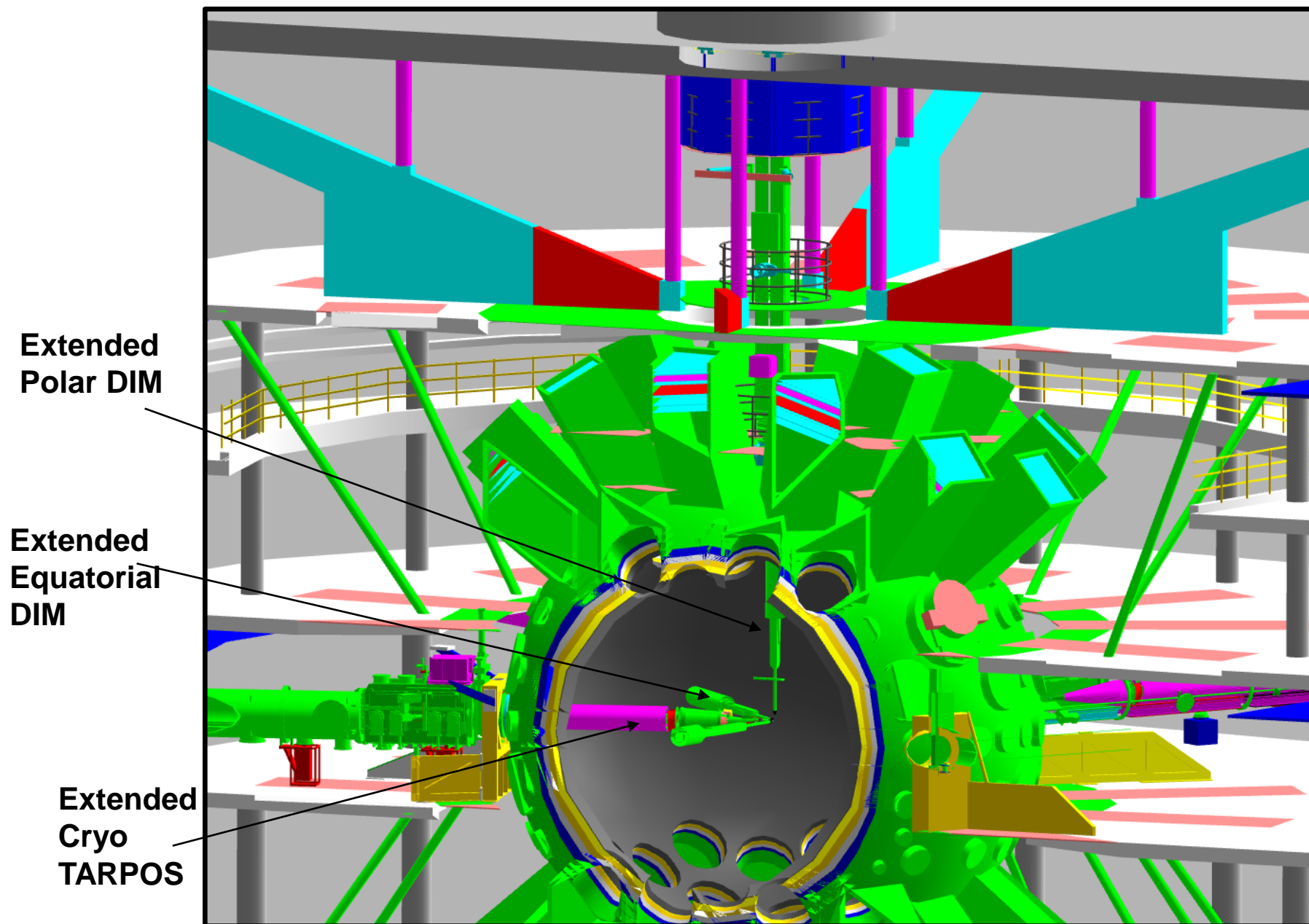
Sectional View of the Target Bay



MCNP Target Bay Model



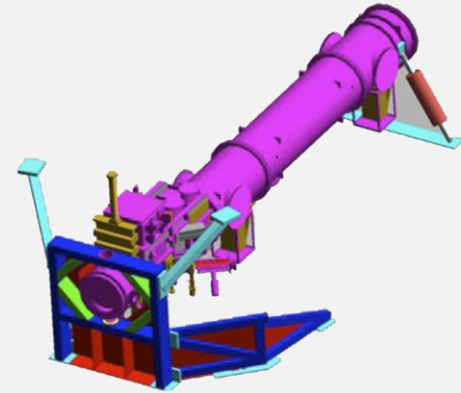
TB model: close-up sectional view



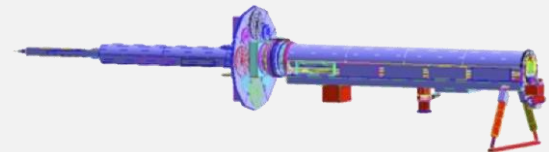
Features of the MCNP Target Bay model

- Structures including the floors, walls, support columns, braces, guard railing, and maintenance platforms
- Target Chamber with 120 diagnostic ports and 24 direct-drive ports
- Forty eight Final Optics Assemblies (FOAs)
- Target positioners (Cryo TARPOS and TARPOS) in the extended and retracted positions
- Target Alignment System (TASPOS)
- Three Diagnostic Instrument Manipulators (DIMs) in the extended and retracted positions
- X-ray diagnostics instruments: Dante and FFLEX
- Magnetic Recoil Spectrometer (MRS)

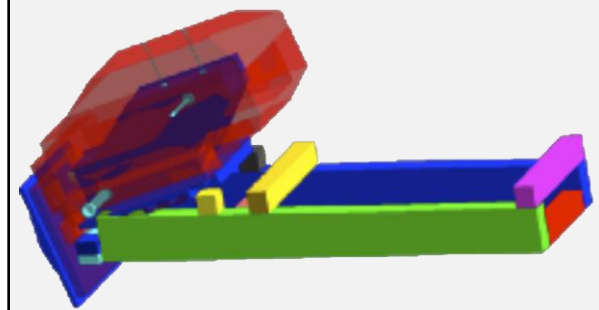
CryoTARPOS



DIM

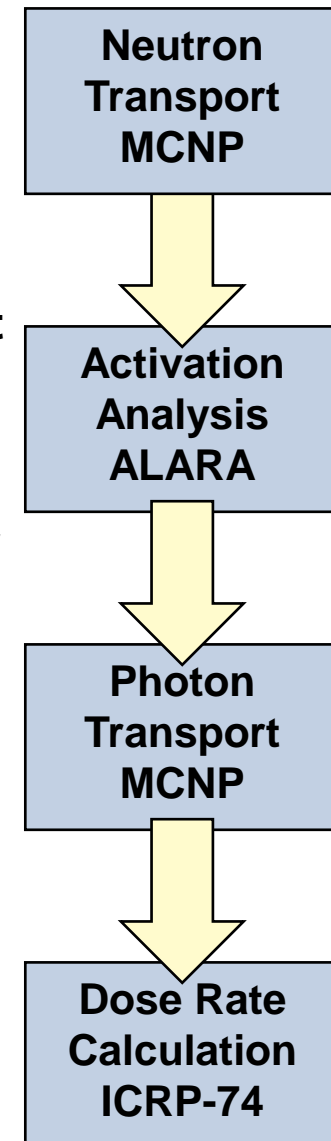


MRS



Methodology used by AAMI to estimate dose rates

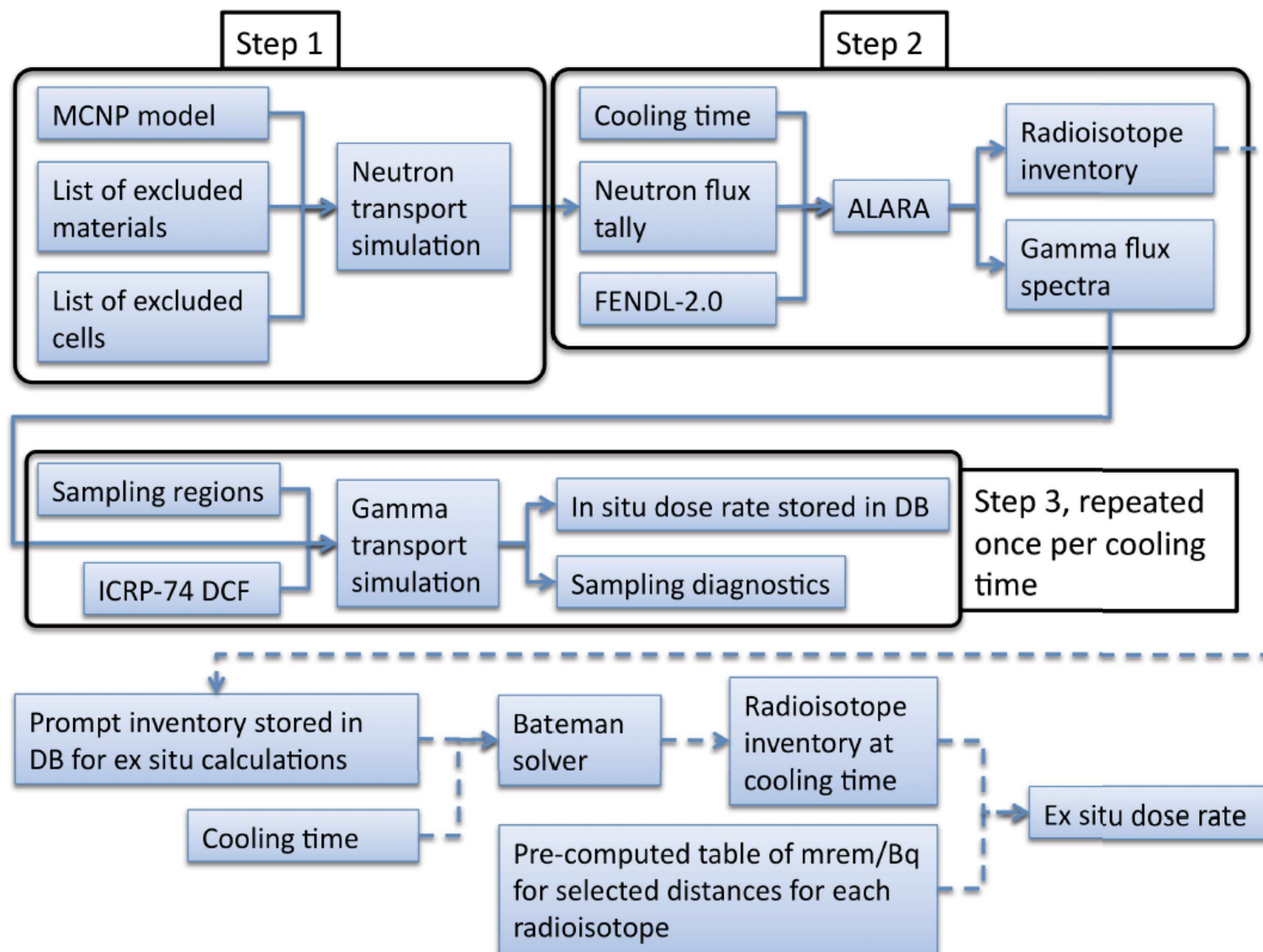
- AAMI automates the dose rate calculations by conducting the following three steps:
 - **Step 1**: Neutron transport calculation using the MCNP 3D model and FENDL-2.1 data library to obtain 175-group flux spectra in each component of interest
 - **Step 2**: Activation analysis of components using the activation code, ALARA, to compute the γ -ray intensities and spectra for each cell and for several different cooling times after a shot
 - **Step 3**: γ -rays computed in the second step are sampled and emitted from each activated component, and propagated by a transport simulation through the entire MCNP model of the Target Bay



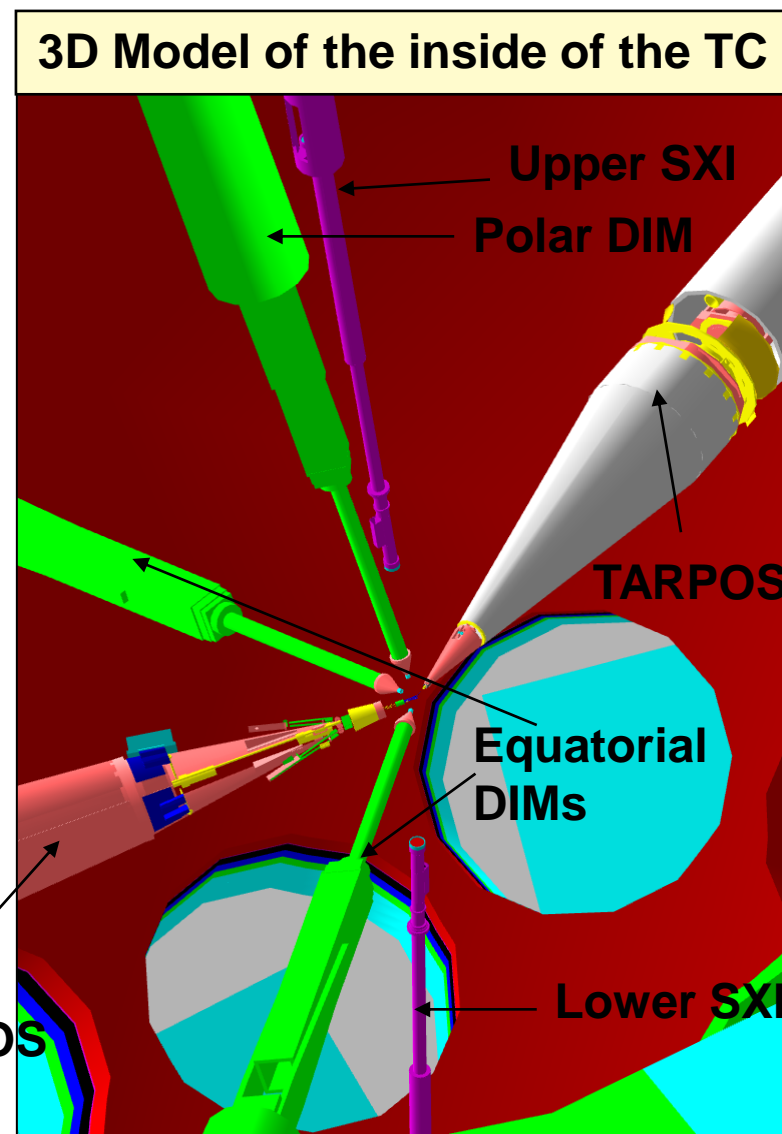
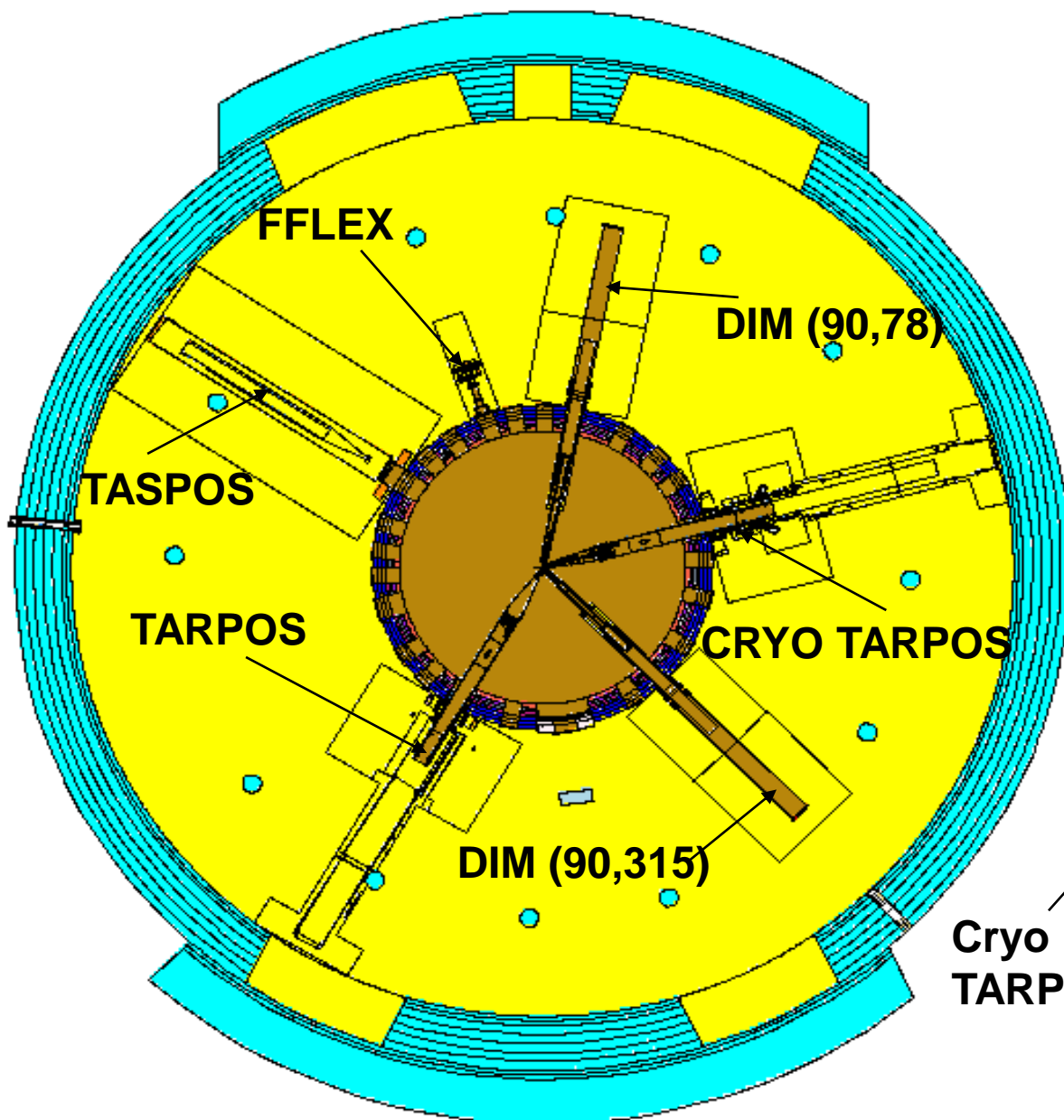
Methodology used by AAMI to estimate dose rates (Cont.)

- **Gamma transport performed with user provided source subroutine for MCNP**
- **Volume-based sampling used with weight adjustment to correct bias for source strength**
- **γ -ray fluxes are tallied using a fine 3-D grid over the entire Target Bay, and are converted into dose rates using the ICRP-74 anterior-posterior effective fluence to dose conversion coefficients**
- **3-D dose rate maps for different cooling times are stored in a database**

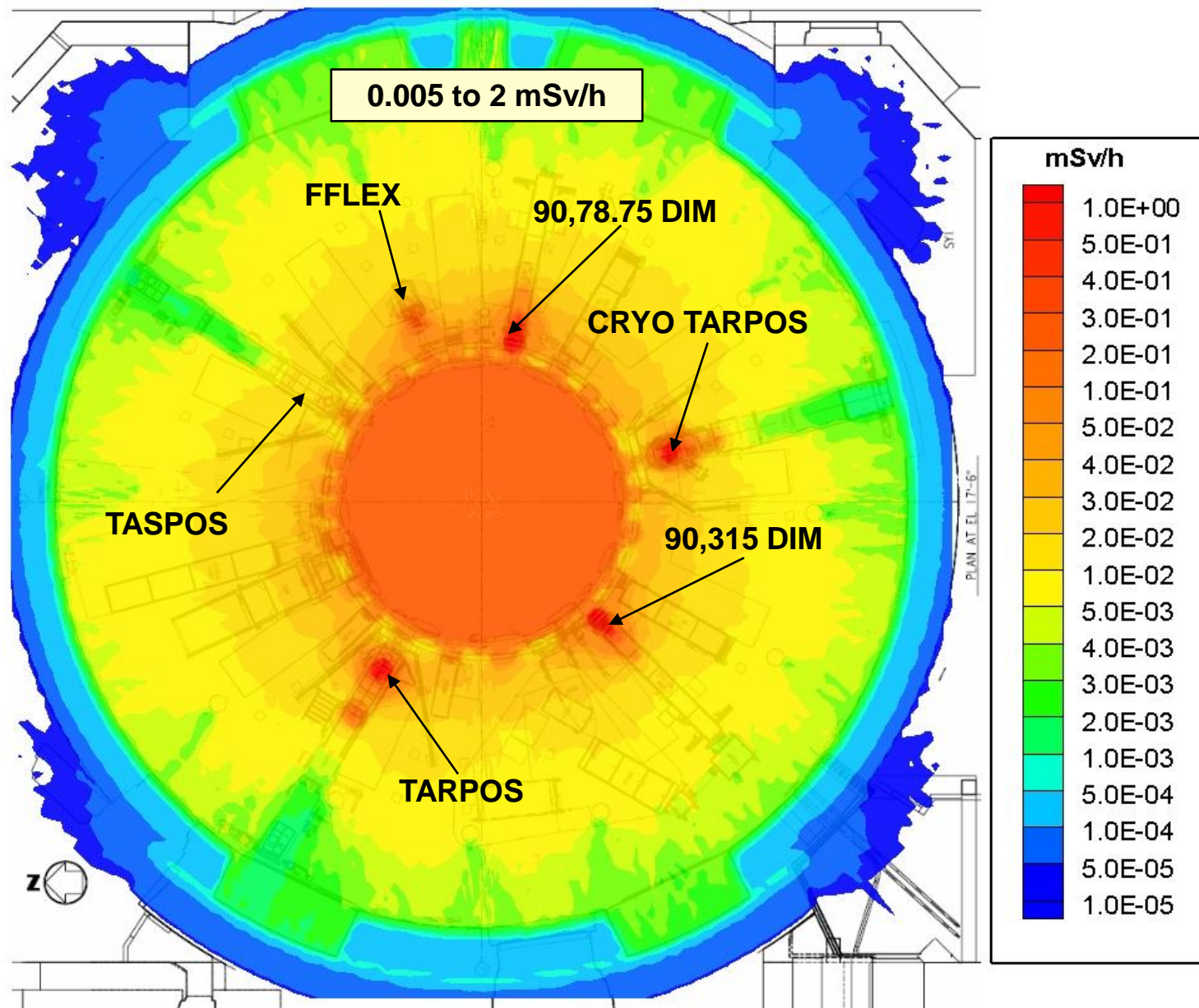
AAMI flow chart



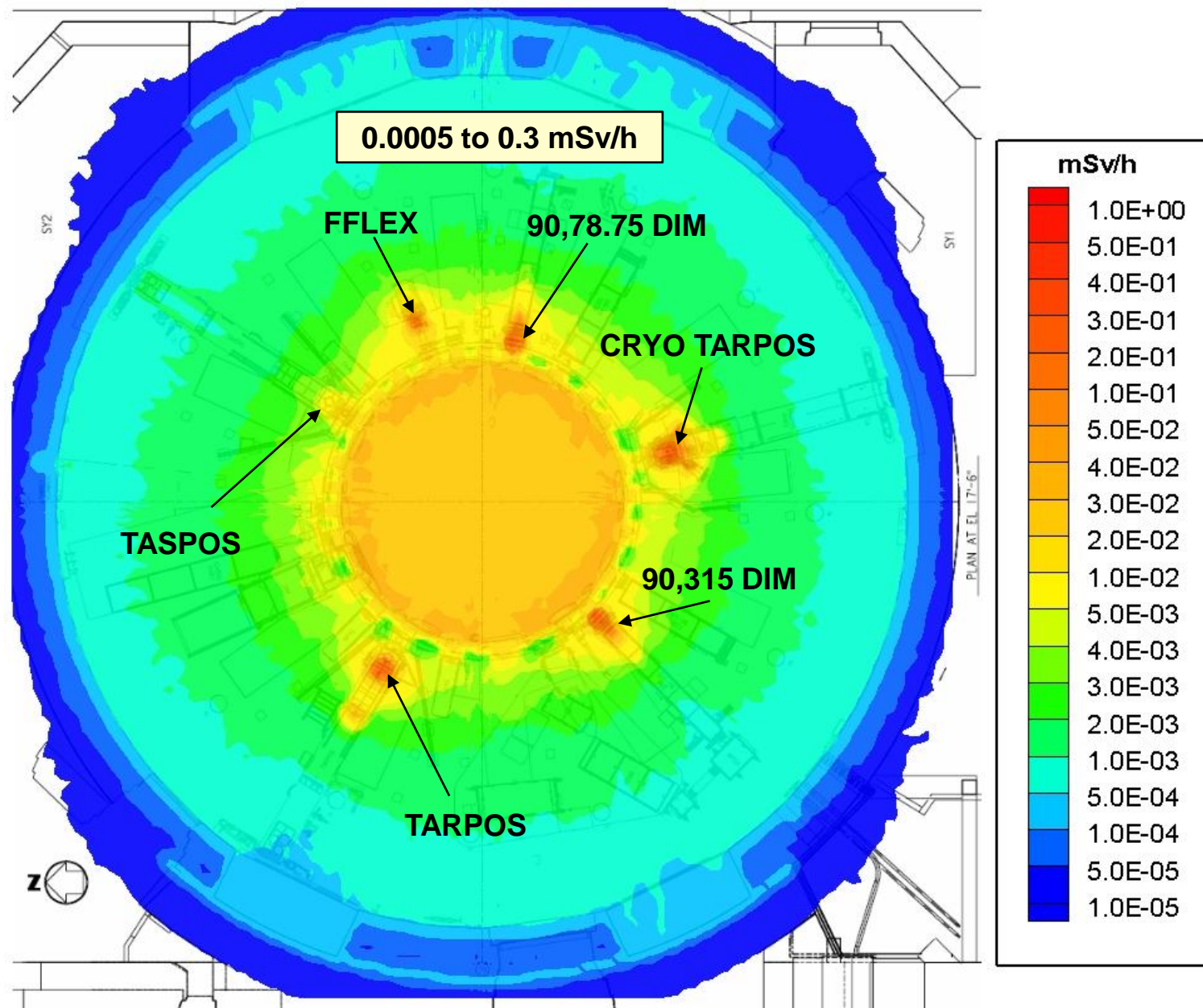
MCNP model of the Target Chamber during a shot



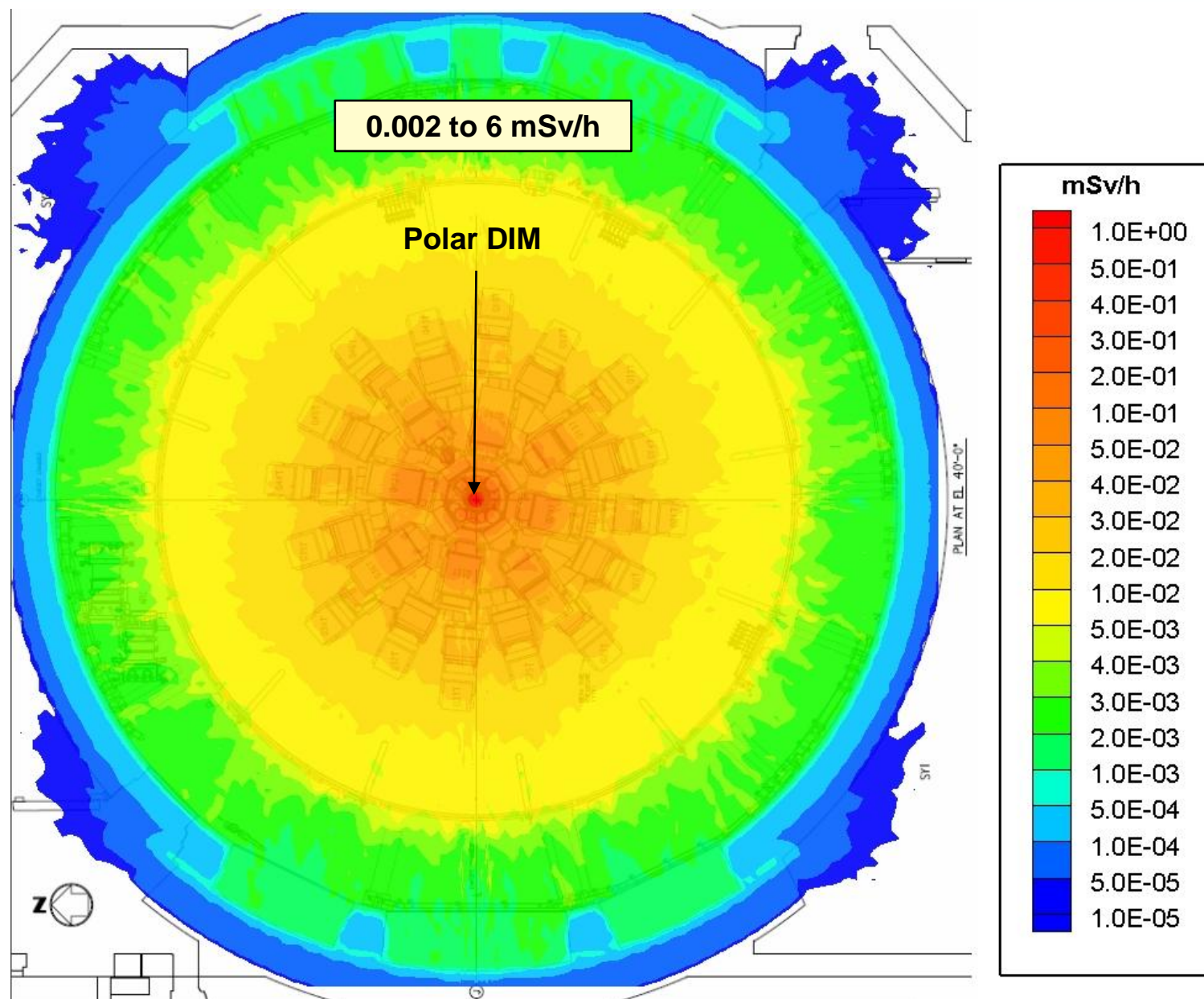
Dose rate map at Target Chamber equatorial plane following a 20MJ/7.1x10¹⁸ shot (5 days cooling)



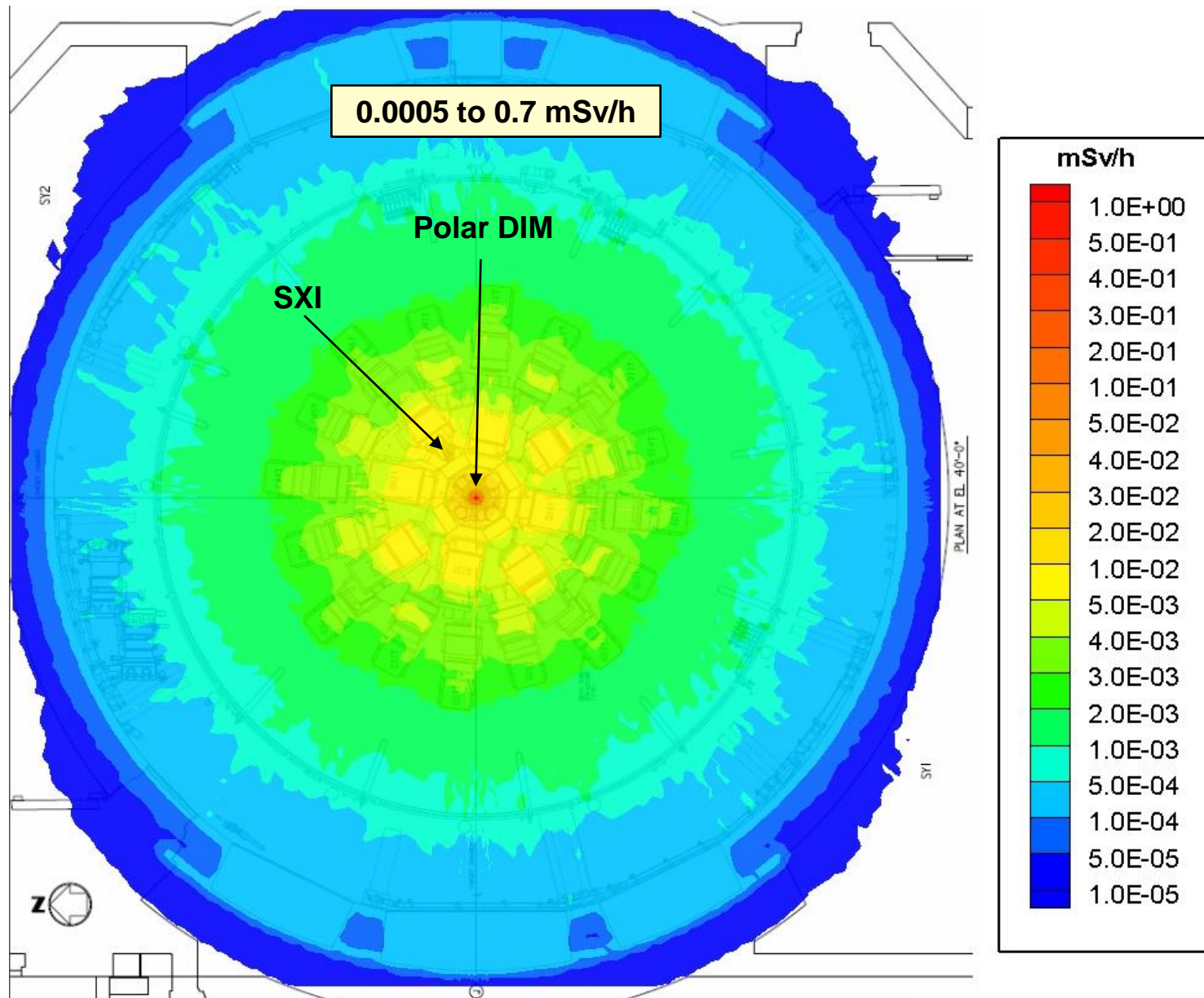
Dose rate map at Target Chamber equatorial plane following a 20MJ/7.1x10¹⁸ shot (7 days cooling)



Dose rate map on platform above Target Chamber following a 20MJ/7.1x10¹⁸ shot (5 days cooling)



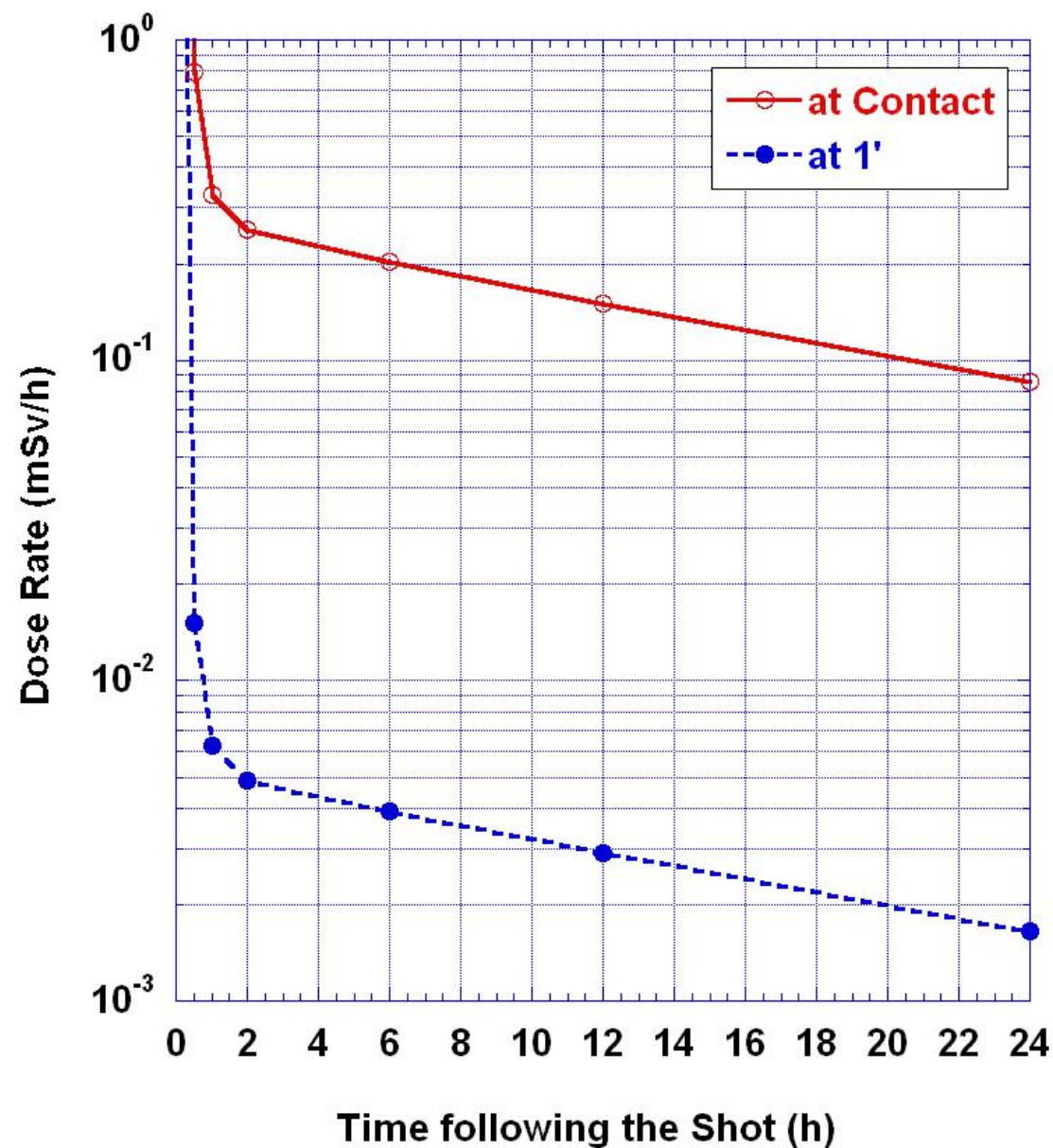
Dose rate map on platform above Target Chamber following a 20MJ/7.1x10¹⁸ shot (7 days cooling)



Dominant contributors to dose inside the Target Bay

- Large number of aluminum and stainless steel components are activated and the principal contributors are:
- Short term
 - ✓ ^{28}Al ($T_{1/2} = 2.2 \text{ m}$; $\langle\gamma\rangle = 1.78 \text{ MeV}$)
 - ✓ ^{27}Mg ($T_{1/2} = 9.5 \text{ m}$; $\langle\gamma\rangle = 0.9 \text{ MeV}$)
- Intermediate term
 - ✓ ^{56}Mn ($T_{1/2} = 2.6 \text{ h}$; $\langle\gamma\rangle = 1.7 \text{ MeV}$)
 - ✓ ^{24}Na ($T_{1/2} = 14.7 \text{ h}$; $\langle\gamma\rangle = 4.1 \text{ MeV}$)
- Long term
 - ✓ ^{58}Co ($T_{1/2} = 70.9 \text{ d}$; $\langle\gamma\rangle = 0.8 \text{ MeV}$)
 - ✓ ^{54}Mn ($T_{1/2} = 312.2 \text{ d}$; $\langle\gamma\rangle = 0.8 \text{ MeV}$)

Dose rates near polar DIM after 10^{15} shot

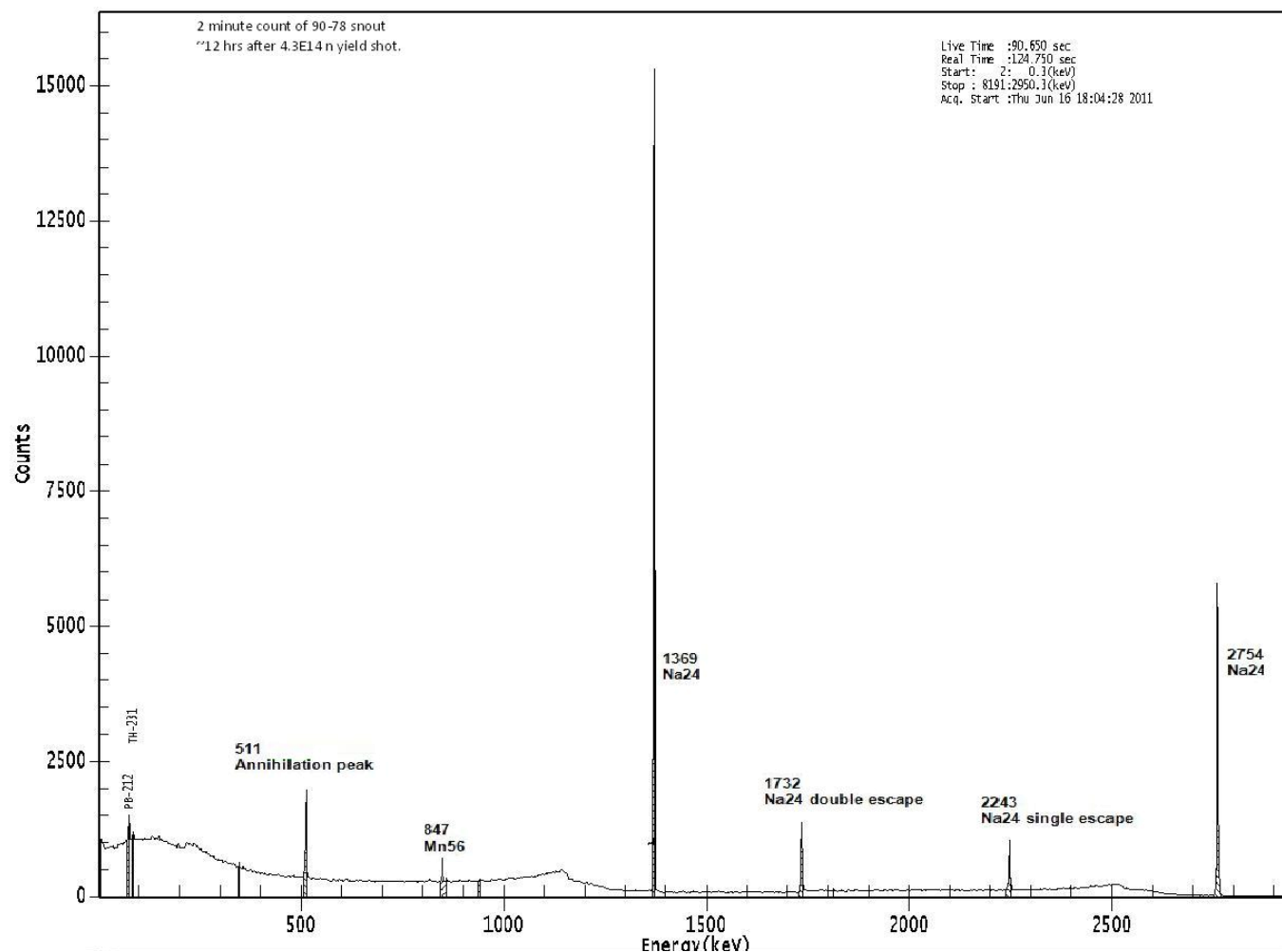


Dose rate at 1' from tip of the snout:

- 4 $\mu\text{Sv/h}$ after 6 h
- 3 $\mu\text{Sv/h}$ after 12 h
- 1.7 $\mu\text{Sv/h}$ after 1 day

Gamma spectrometry

- Spectrum obtained on a DIM snout 12 hours following 4.3×10^{14} shot
- Measured snout dose rates are typically between 0.03 and 0.15 mSv/h on contact when they are removed 4 hours after a 5×10^{14} shot
- Gamma spec readings of Target Bay and Target Chamber diagnostic components show primarily ^{24}Na and ^{56}Mn activities



NEET is a web-based application

RadExpo - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://localhost/war/RadExpo.html#

ieee_abstract.pdf Frank's Towing, Road... Most Visited Getting Started Latest Headlines

mySQL LIMIT Search Up Highlight mySQL LIMIT

Carpinteria, California v... Azure Standard - Sign In Access Denied RadExpo MySQL :: MySQL 5.0 Re... MySQL :: MySQL 5.0 Re... Solve PHP Fatal error: A... Bug 420869 - Script sta... JS_DEFAULT_SCRIPT_5... SQL Limit - MySQL Limit -...

List of tables

- Tables
 - Nuclear data
 - Simulated data
 - Geometric data
 - Measurements
 - Internal data
 - Task data
 - Shot data
 - Schedules
 - Task schedule
 - Shot schedule

Console

```
Loading table
'shotschedule', this
might take a few
seconds.
```

Show floor maps

Database editor

Shot schedule

Delete selected Copy selected Add entry Load Bro

Date/time	Shot type(DD,D	Yield[n/shot]
Sat Aug 01 2020 10:00:00 PDT	DT	1000000000000000000
Tue Sep 01 2020 10:00:00 PDT	DT	7800000000000000000
Tue Dec 01 2020 10:00:00 PST	DT	1000000000000
Fri Jan 01 2021 10:00:00 PST	DT	7800000000000000000

Commit changes to database Cancel changes

Exposures per task

Compute All tasks AAMI Show subtask table

Task	Date/time	Dose [mrem]	Max. dose rate	Commen
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Dose rates

Component All compone Location Select exposure AAMI

Date/Time	Dose rate [mrem/h]	Fraction of total
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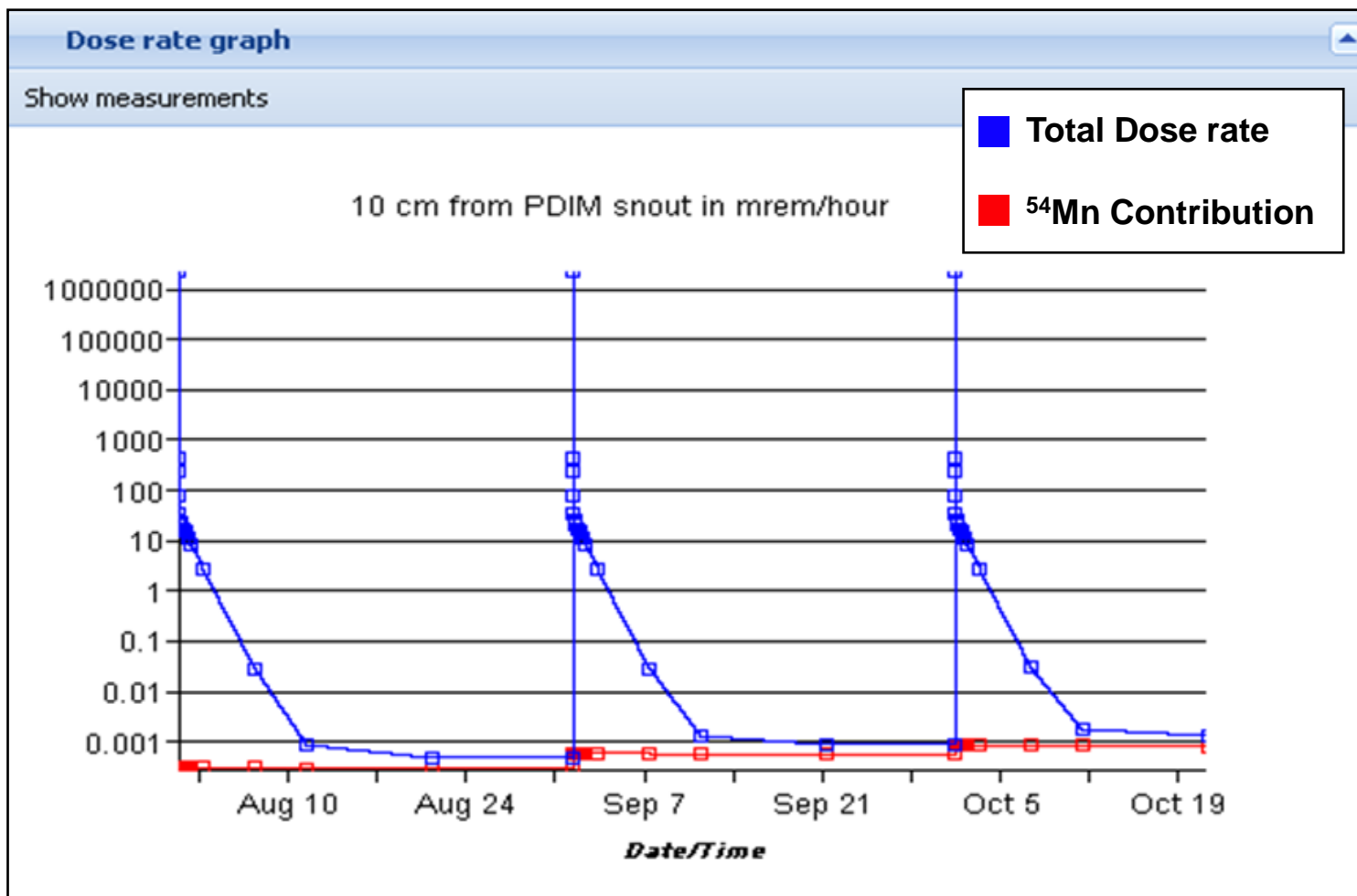
Compute Select component Select nucli

Dose rate graph

Show measurements

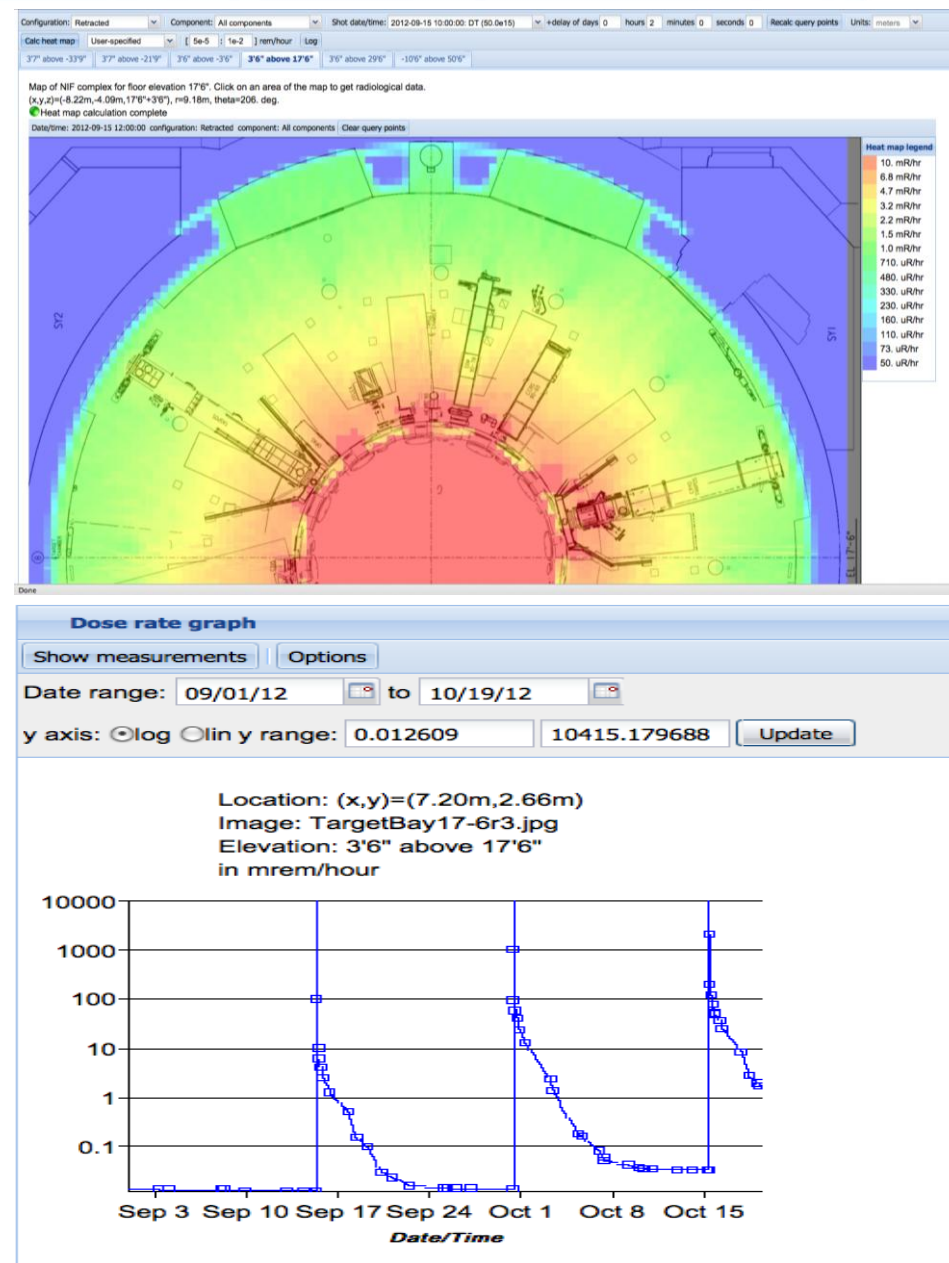
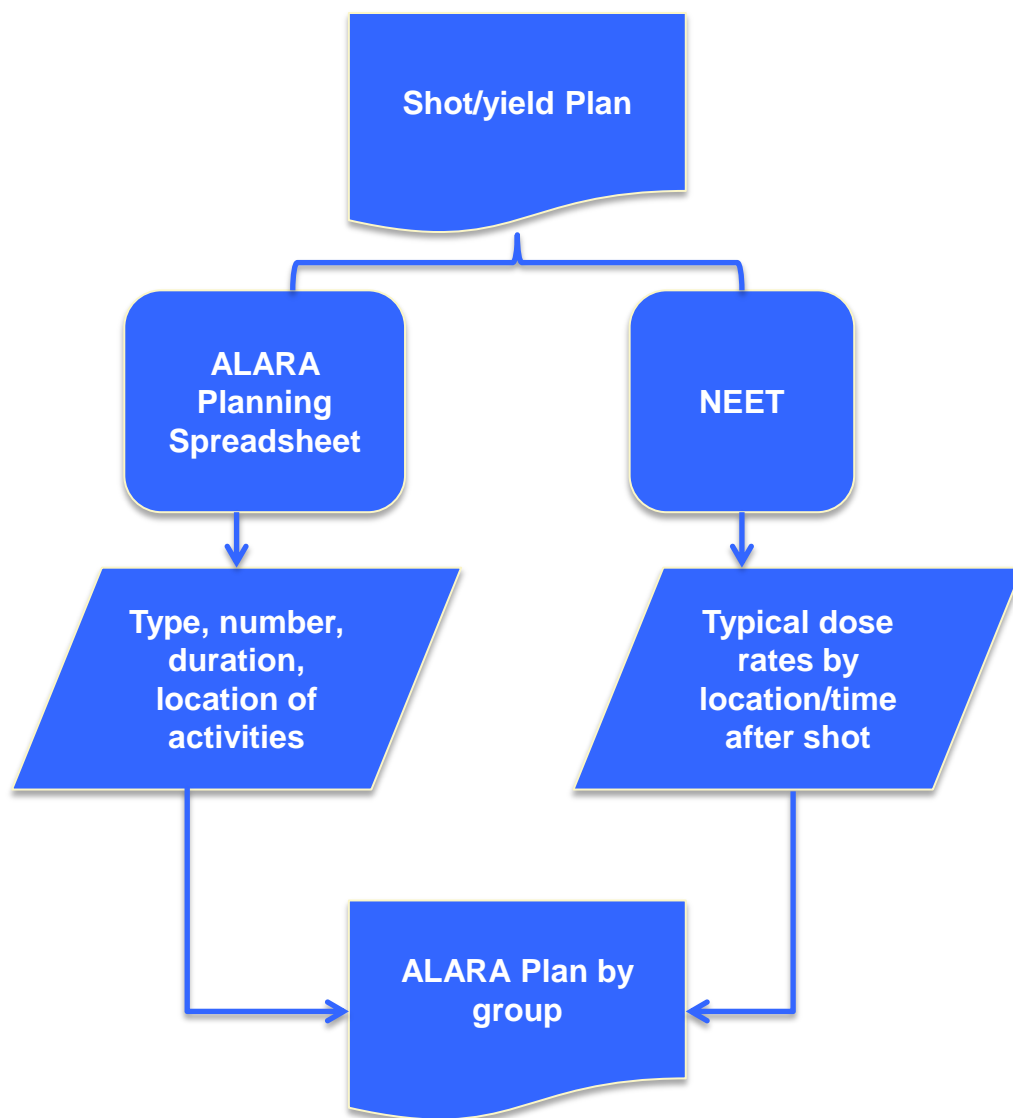
Done

Dose rates following a set of 10^{16} shots



Radiation environment is dominated by short-lived isotopes

NEET is used to develop annual ALARA Plan



Summary

- **A detailed model of the TB has been developed to characterize the radiation environment within the TB following different categories of shots**
- **A set of computational tools was developed to help in estimating potential radiation exposure to workers from activated materials inside the Target Bay**
- **The Automated ALARA-MCNP Interface (AAMI) provides an efficient, automated mechanism to perform the series of calculations required to create dose rate maps for the entire facility**
- **The NIF Exposure Estimation Tool (NEET) is a web-based application that combines the information computed by AAMI with a given shot schedule to compute and display dose rate maps as a function of time**
- **Components close to TCC during a shot, like parts of the CryoTARPOS, TARPOS and the 3 DIMs represent a major source of gamma decay after being retracted outside the TC**

Summary (cont.)

- Seven days following a 20 MJ shot, the dose rates in the immediate vicinity of the retracted components drop to < 0.2 mSv/h and the general ambient dose rate near the TC drops to < 0.01 mSv/h
- Primary NIF components, including the Target Chamber, Diagnostics and Beam Line Components, are constructed of aluminum
- Near-term Target Bay accessibility is driven by the decay of the aluminum activation product ^{24}Na
- NEET results are used to develop annual ALARA Plan
- Worker doses are tracked and managed using Sentinel software

NIF

